FRACTIONATION AND EQUILIBRATION IN DIOGENITES, Roger H. Hewins, Geological Sciences, Rutgers University, New Brunswick, N.J. 08903.

Introduction Diogenites play a key role in models of igneous and breccia evolution of meteorite parent bodies. They are often taken to be very simple, although phase compositions are diagnostic of individual diogenites (1), Garland has two distinct pyroxenite phase assemblages (2) and diogenite pyroxenes fall into three Al-Cr groups despite limited Mg-Fe-Ca variation (3) the igneous evolution of diogenites is difficult to reconstruct for those which contain only crystal fragments. This paper therefore considers mainly lithic clast material in Roda, Garland and ALHA 77256.

Petrography Diogenites contain clasts of orthopyroxene cumulates (variably shocked or annealed) with minor chromite, olivine (both mainly cumulus) and plagioclase. Accessory minerals are troilite, tridymite, kamacite and augite. There is textural evidence of trapped liquid (intercumulus material). At orthopyroxene-olivine grain boundaries in ALHA 77256 (PS is one large clast), interstitial plagioclase is associated with troilite and wormy chromite. Locally orthopyroxene is poikilitic to or mantles small olivine grains. In Roda an assemblage of any 2-3 of chromite, plagioclase, tridymite and troilite occurs along orthopyroxene grain boundaries and as patches inside pyroxene grains. Garland contains olivine partly replaced by an orthopyroxene-troilite intergrowth in contact with orthopyroxene (see also (2)) and rare plagioclase interstitial to orthopyroxene.

Orthopyroxene The three Al-Cr groups reported by (3) are apparent in the more abundant data of (4). Fig. 1 shows revised boundary lines for groups I-III. There is some overlap of compositions, e.g. of Garland II and Roda III, and Aioun el Atrouss data straddle the II-III boundary. (Assemblage II of (2) is very subordinate to I in Garland.) "Late" orthopyroxene associated with plagioclase in Roda and ALHA 77256 (open symbols, Fig. 2) is the most Al-poor in these rocks. It reaches the same Al contents as group I pyroxene but is indistinguishable from normal (III) pyroxene in En-Wo. Pyroxene associated with plagioclase in Garland is normal group I orthopyroxene. The pyroxene from reaction of Garland olivine with liquid is unusually Al-poor (open symbols, Fig. 2). Orthopyroxene equilibrated with augite in diogenites at about 900°C, using (5).

Spinel Diogenite spinels show a correlation of Mg with Al and Fe with Cr as in some lunar spinels (6). Interpreting the data as a fractionation trend, ALHA 77256 spinel crystallized at the highest temperatures and Garland at the lowest. There is a similar trend within ALHA 77256: cumulus spinel is Mg-Al-rich and intercumulus spinel is Fe-Cr-rich.

Orthopyroxene-Spinel Both orthopyroxene and spinel are fractionated to Al-poor compositions in ALHA 77256 and there is a general correlation of compositions of these phases in diogenites. Roda and Garland contain some clasts with Al in both phases higher than typical. Fig. 3 shows Al distribution between orthopyroxene and spinel: reference lines are for compositions equilibrated about 100° apart, after (7). Intercumulus material in ALHA 77256 appears to record lower temperatures than cumulus material. The same is true if Al/Cr of pyroxene is plotted against Al/Cr of spinel, again using a reference isotherm from (7). From these figures, Roda orthopyroxene-spinel records temperatures similar to early ALHA 77256 but Garland records lower temperatures similar to late ALHA 77256.

Orthopyroxene-Plagioclase Coexisting orthopyroxene and plagioclase range from En77-An92 to En67-An85. ALHA 77256 plots at the inferred high
temperature end of this trend, Roda data cover much of this range and Garland is low temperature. Temperature inferences based on plagioclase thus match those based on spinel.

Olivine-Spinel Partitioning of Fe and Mg between olivine and spinel versus Al/Cr in spinel is treated in Fig. 4 after (8-9). Cumulus spinel again records higher temperature (about 900°C) than intercumulus spinel. Spinel does not coexist closely with olivine in most diogenites. For Roda, Ellemeet and Aioun el Atrouss, estimates were made by pairing Al-rich spinel with Mg-rich olivine and Al-poor spinel with Fe-rich olivine. For Garland, olivine and spinel occur in the same clasts but are not adjacent. Olivine and spinel may not generally be in equilibrium in diogenites.

Olivine-Orthopyroxene Fe-Mg partitioning was investigated following (10). Since the compositions are close to those for which isotherms cross over, no temperature information could be extracted. The partition coefficient is about 1.2.

Discussion and Conclusions Despite the limited range of Fe/Mg ratios, there is evidence of fractionation in diogenites. Orthopyroxene and spinel progress from Al-rich to Al-poor within ALHA 77256. Pyroxene-spinel-plagioclase trends suggest a similar progression from ALHA 77256 to Roda to Garland (I), which may therefore represent a fractionation sequence. Plagioclase, tridymite, troilite and associated pyroxene indicate the presence of trapped liquid, which cannot be ignored in attempting to explain variations in trace elements between and within diogenites (11-12).

The present range of Fe/Mg variation in diogenites is smaller than expected. Mechanisms which would explain limited Fe-Mg but varied Al-Cr include magma mixing or diffusion-controlled crystallization (13) and subsolidus reequilibration. Both crystallographic (14) and TEM (15) studies of diogenite orthopyroxene have suggested long residence at high temperatures. Possibly cumulus pyroxene has exchanged Fe/Mg with varying amounts of chromite, trapped liquid or migrating liquid (16) or adjacent layers of different composition, while Al-Cr concentrations have changed much less. Since polymict breccias such as howardites and mesosiderites show much wider ranges of Fe-Mg in pyroxene, it will be interesting to enquire if they show evidence of an equal length of time at high temperatures. The question of whether pyroxene in these breccias is identical to diogenite remains important. The presence of tetrataenite in Roda (17) as in mesosiderites indicates that diogenites have cooled very slowly at low temperatures (post-brecciation).

References